United States Department of Agriculture

Cover Crop Mixes for Soil Health

Year 2 Progress Report

USDA Natural Resources Conservation Service Corvallis Plant Materials Center
Annual Progress Report prepared by Annie Young-Mathews, January 2015

Summary of Preliminary Results

- Soil Health Nutrient Tool scores and soil microbial activity continue to increase after two years of no-till and cover crop treatments. Higher soil microbial activity generally indicates greater soil fertility.
- Overall soil organic carbon levels and available phosphorus have increased in the top 6 inches, while organic nitrogen has declined.
- Soil penetration resistance declined the first year, but increased somewhat the second year, while bulk density continued to increase, showing varying effects of no-till on soil compaction. Increased bulk density might be attributable to increased aggregate formation, which will be tested by measuring infiltration rates and aggregate stability at the end of Year 3.
- Cover crop performance was poor in Year 2, due to late planting, bad weather, and heavy predation by birds and slugs. None of the treatments achieved more than 40% canopy cover, and biomass production of the catch-up pea cover crop was only 2,000 lb/acre, well below the recommended 90% cover and 4,000 lb/acre biomass for this conservation practice.
- Slug control continues to be a major challenge in successfully managing a no-till cover-cropped rotation in western Oregon.

Introduction

The Corvallis Plant Materials Center (PMC), along with six other PMCs in Washington, California, Missouri, North Dakota, Maryland, and Florida, is participating in a national study looking at the effect of different cover crop mixes and seeding rates on soil health. The mixes being tested in this national study are composed of regionally adapted members of three functional groups: grasses, legumes, and brassicas. After termination of the cover crops, a regionally adapted commodity crop was planted in all plots (barley, field corn, or sweet corn). Fiscal Year 2014 constituted the second year of this 3-year study. Results from this study will help inform local recommendations for effective cover crop mixes and seeding rates to address different resource concerns. This report offers a preliminary analysis of data from the first two years of the study, and conclusions may change over the next year as more data are collected.

Experimental Design and Methods

This trial uses a 3 x 3 factorial arrangement of the cover crop mix and seeding rate treatments, along with a non-cover cropped control (sprayed out this year to prevent weed growth), in a randomized complete block design with four replications. The three cover crop mixes are: a 2-species mix composed of 50% cereal rye and 50% crimson clover; a 4-species mix of 45% cereal rye, 22.5% crimson clover, 22.5% hairy vetch, and 10% forage radish; and a 6-species mix of 22.5% cereal rye, 22.5% oats, 22.5% crimson clover, 22.5% hairy vetch, 5% forage radish, and 5% forage turnip (percentages are based on the number of seeds in the mix, not the weight). Mixes were seeded at three rates: 20, 40, and 60 seeds per square foot. Plots are 30 x 30 ft with 6-ft alleys between blocks.

After our Year 1 sweet corn crop was harvested in early September 2013, the stalks were flail mowed and the field was sprayed with glyphosate in mid-September. In late September, we collected data on soil temperature, moisture, bulk density, penetration resistance, and soil samples for microbial activity and chemical/nutrient analysis. We planned to no-till plant our next cover crops the first week of October, but due to the government shut down we weren't able to plant the cover crop plots until October 17, 2013. We then had a 2-week period of cool weather (soil surface temperatures from 41–64°F) with no rain, which provided the perfect conditions for birds to eat the exposed seed and slugs to eat the slowly germinating seedlings. We applied slug bait to the field a few days after planting, but much damage was already done. When it became apparent that no rain was in the forecast, we set up irrigation on the field and irrigated on October 25th and 29th, but germination was slow and patchy. Plot photos were taken every 15 days and percent canopy cover and height were recorded every 30 days over the winter.

Corvallis experienced two severe winter storms, one in early December, 2013, with 6+ inches of snow and temperatures staying below freezing for six days straight and dipping as low as 2°F, and another in early February, 2014, with 14 inches of snow and temperatures staying below freezing for three days straight. By April 2014, it was apparent that the cover crop treatments were a failure for the year, with the majority of plant cover in each plot from weeds and volunteer turnips that had gone to seed the previous season. Therefore, cover crop biomass samples were not collected and all plots were flail mowed and sprayed with glyphosate on April 25.

In an attempt to provide some nitrogen for the summer commodity crop, on April 28 we planted a pea (*Pisum sativum* L.) catch-up cover crop on all treatment plots (except the controls) at a rate of about 100 lb/acre. The peas were irrigated as needed (about 1 in/week when there was no rain) and we collected biomass samples from each plot prior to rolling and spraying them out on July 1st. Soil samples were collected for Haney microbial/chemical analysis and data on soil temperature and moisture were collected from all plots immediately following pea termination. Sweet corn *(Zea mays* L.) was no-till planted July 7, and slug bait was applied to the field right after planting. Corn received about one inch of irrigation per week throughout the summer. Corn was flail mowed to terminate the crop on September 9 with no harvestable yield (plants

were yellow and severely stunted, presumably due to N deficiency). We again collected fall data on soil temperature, moisture, bulk density, penetration resistance, and samples for microbial activity and chemical analysis immediately after the corn was mowed, and the Year 3 cover crop plots were no-till planted September 15-17, 2014. Slug bait was applied, and cover crops were irrigated weekly until consistent fall rains began in mid-October.

Results and Discussion

Cover Crop and Commodity Crop Performance

NRCS Cover Crop practice (340) states that for most purposes the combined canopy and surface cover of a cover crop should reach at least 90% and above ground (dry weight) biomass production should be at least 4,000 lb/acre for the practice to be considered successful. In the first year of this study, most cover crop treatments had over 90% canopy cover by 60 days after planting (DAP), and had produced over 8,000 lb/acre dry matter by the time they were terminated in late April, 2013. However, Year 2 establishment was very poor and the combined canopy cover of planted cover crops plus weeds never reached above 40% (Figure 1). Most cover was provided by residue from the prior year's corn and cover crops that slowly began to break down over the winter. The average height of the cover crop canopy at termination in April 2014 was only 15 inches.

After terminating the failed cover crop plots, by June 2014 the 2-month catch crop of peas resulted in a total living canopy cover over 90% (Figure 1), composed of 57% peas, 29% weeds, and 8% volunteers or regrowth of cover crop species. The average height of pea cover was 59 inches and mean above ground biomass was 2,000 lb/acre with a nitrogen content of 2.4%. According to the OSU cover crop calculator (Andrews et al., 2012), this pea biomass would result in an estimated plant-available nitrogen (PAN) contribution of only 14 lb/acre to the subsequent corn crop. General guidelines for growing sweet corn in western Oregon recommend

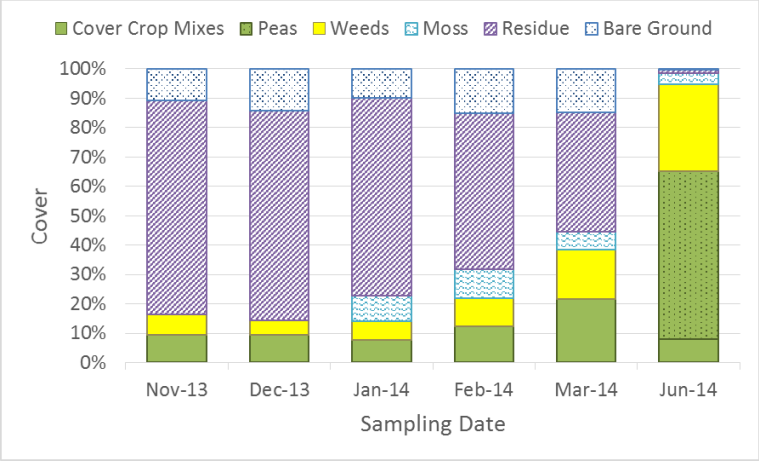

Figure 1. *Average canopy cover of all cover cropped plots at the Corvallis Plant Materials Center over the course of the 2013-2014 growing season according to cover type.*

Figure 2*. Sweet corn crop at the Corvallis PMC in early September 2014, showing yellowed leaves, stunted growth, and no harvestable ears.*

30 lb N/acre banded at planting, unless following a legume cover crop, and a sidedress application of 40 to 165 lb N/acre depending on the pre-sidedress nitrate soil test results (Hart et al., 2010).

Probably due to this lack of PAN, as well as the late planting date, there was no harvestable yield of sweet corn by September 2014 (Figure 2). Had we waited another month or more, we may have obtained a meager corn harvest from some plots, but we decided to terminate the crop with no yield in order to allow early planting of the Year 3 cover crop to avoid repeating the same problems.

Indicators of Soil Health: Physical, Chemical, and Biological

Cover crops and no-till are two practices that can be used as part of a soil management system to improve soil health. However, soil health is difficult to measure directly, so soil quality indicators (SQIs) can be used to evaluate how well a soil is functioning and the sustainability of the land use and soil management practices. SQIs are often grouped into three categories: physical, chemical and biological.

Physical Indicators: Soil Compaction

Bulk density is one indicator of soil compaction and porosity (needed to allow proper movement of air and water through the soil); it is calculated by dividing the dry weight of the soil by the volume. For silty soils like ours, ideal bulk density for plant growth is less than 1.40 g/cm^3 and root growth is generally restricted at bulk densities above 1.65 g/cm^3 (USDA-NRCS, 2011). Across all plots we've seen a significant increase in bulk density over the two years since we began no-till treatments, from an average of 1.22 to 1.47 g/cm^3 (Figure 3). An increase in bulk

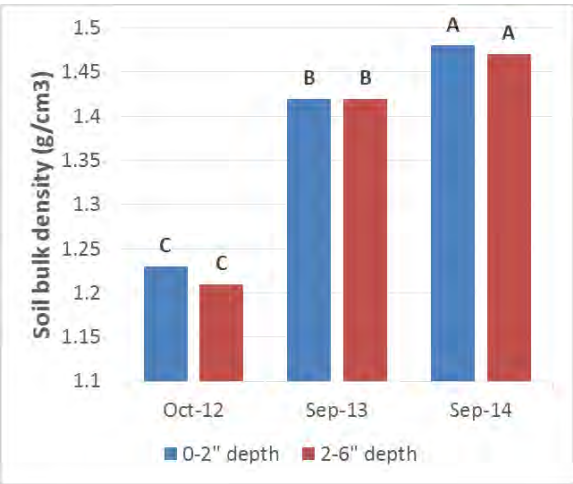

Figure 3. *Average soil bulk density of all plots in the Soil Health study at the Corvallis Plant Materials Center at the start of the study (Oct. 2012), and after one year (Sept. 2013) and two years (Sept. 2014) of no-till and cover cropping treatments. Bars with the same letter are not significantly different according to Tukey HSD tests at α=0.05.*

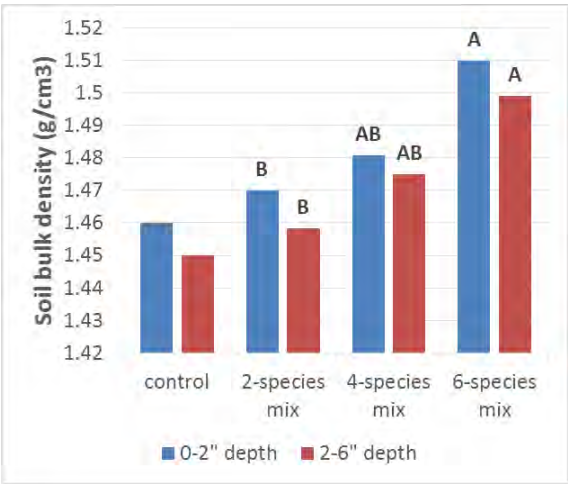

Figure 4. *Average soil bulk density according to three cover crop mixes, plus the non-cover cropped control, at the Corvallis Plant Materials Center, sampled in September 2014 after two years of no-till and cover cropping. Bars with the same letter are not significantly different according to Tukey HSD tests at α=0.05.*

density from the baseline value is to be expected, due to normal settling of the soil fluffed by tillage. However, the increasing bulk density may also be partly due to equipment compaction, as well as some aggregate formation. Other studies have shown that conversion to no-till led to increases in bulk density in the upper layer of soil, along with increased infiltration and improved aggregate stability (Hubbard et al., 1994; Tebrügge and Düring, 1999). At the end of Year 2, bulk density was higher in plots where the 6-species mix was grown than in the 2-species plots (Figure 4). This suggests that the plant roots and associated soil microbes in the more complex cover crop mix may be accelerating the process of aggregate formation, which we can test by measuring infiltration rates and aggregate stability at the end of Year 3.

Another indicator of soil compaction is the penetration resistance measured with a soil compaction tester, or penetrometer. A resistance of 300 pounds per square inch (psi) generally limits root growth, but roots may still penetrate the soil if natural pores or cracks are present. In our plots we didn't see any significant effects of cover crop treatments yet, but overall soil resistance decreased significantly at all three depths after the first year, and then increased somewhat after the second year, though still remaining below the original levels and below the 300 psi threshold (Figure 5). This increase in resistance in Year 2 could be due to the poor performance of the cover crops and lack of root biomass to add organic matter to the soil. Hopefully soil resistance and bulk density data from Year 3 will help us better understand the effects of cover crops and no-till on compaction of our soils.

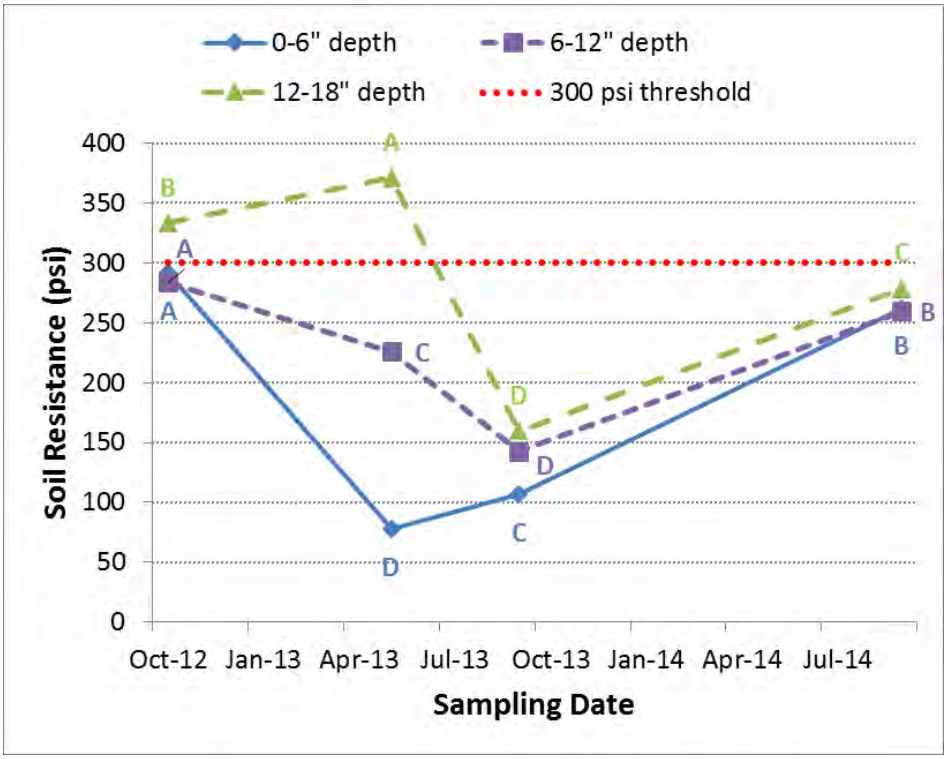

Figure 5. *Mean soil resistance of all plots (N=40) in the Soil Health Study at the Corvallis Plant Materials Center over two years of no-till and cover cropping treatments. Points with the same letter within each depth category are not significantly different in Tukey HSD tests at α=0.05.*

Chemical and Biological Indicators: Soil Health Nutrient Tool

The Soil Health Nutrient Tool (SHNT) is a relatively new suite of laboratory analyses and calculations developed by Dr. Rick Haney of ARS (Haney, no date). The SHNT uses "green chemistry", that is, water and organic acid extracts to perform soil nutrient analyses. Water extractable soil organic C and N values reflect the quality of the energy source that is driving the soil microbial community. The N-P-K values reported with this tool incorporate not only the inorganic nutrients measured in the organic acid extracts, but also the amount of N and P that the soil microbes will provide based on the soil microbial activity (Solvita 1-day CO_2-C), the organic C:N ratio, and N from the plant available organic N pool. Samples were collected from the top 6 inches of soil from 5 composite samples per plot. Results are presented here as an average of all 36 cover cropped plots (excluding controls), since there were no significant effects of cover crop mix or seeding rate for most soil nutrients.

After the first year of cover cropping in our study, the soil organic carbon levels more than doubled, but then dropped back down somewhat in the second year, while nitrogen levels were immediately cut in half and have not recovered (Figure 6). Our first year cover crop mix was dominated by cereal rye and brassicas, with the N-fixing legumes only making up about 40% of the biomass. Thus, the residue feeding the soil microbial community had a relatively high C:N ratio, meaning that much of the N produced by the legumes was likely consumed by soil microbes in order to break down the C-rich residue. Similarly, soil organic C:N ratios increased substantially in Year 1 and then plummeted in Year 2 (Figure 6), reflecting the low biomass

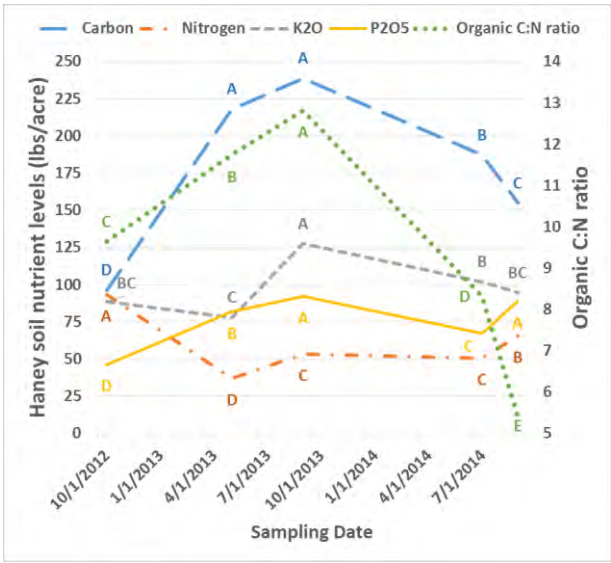

Figure 6. *Average soil nutrient levels in all cover cropped plots (N=36) over two years of the Soil Health Study at the Corvallis Plant Materials Center. Nutrient levels were determined by water and organic acid extraction as part of the Haney Soil Health Nutrient Tool test. Means with the same letter for each nutrient are not significantly different in Tukey HSD tests at α=0.05.*

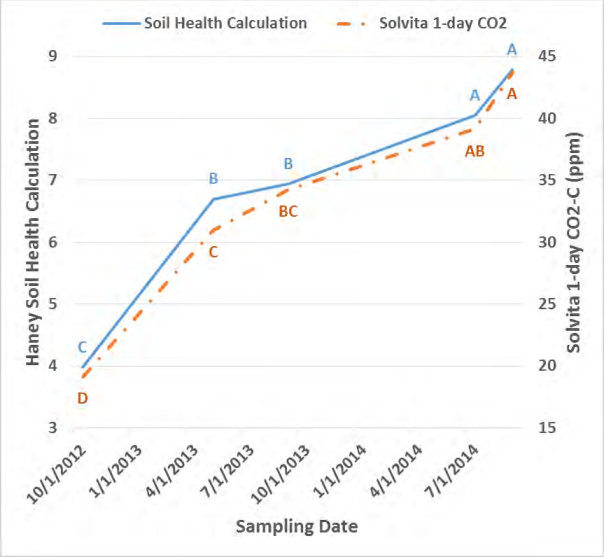

Figure 7. *Average Haney Soil Health Nutrient Tool soil health calculations and Solvita 1-day CO2 (soil respiration) in all cover cropped plots (N=36) over two years of the Soil Health Study at the Corvallis Plant Materials Center. Points with the same letter for each measurement are not significantly different in Tukey HSD tests at α=0.05.*

inputs from the weak cover crops and stunted corn crop in Year 2.

Meanwhile, available P_2O_5 levels have nearly doubled over the two years of the study, while K_2O levels have bounced around but ended up essentially the same at the end of two years as they were at the start of the study (Figure 6). Cereal rye and radish are reported to be very good at scavenging nutrients such as N, P and K from below the rooting depth of most crops, thus making those nutrients more available to subsequent crops when their residue decomposes (Clark, 2007).

The Solvita 1-day CO_2-C is a measure of the microbial activity in the soil and is highly related to the fertility of the soil; in most cases, the higher the number, the more fertile the soil. Overall Solvita levels have steadily increased in our study, more than doubling from baseline levels to those measured at the end of Year 2 (Figure 7). The Solvita trend is closely mirrored by the Soil Health Calculation (Figure 7), one of the final outputs of the SHNT that incorporates the balance of soil organic carbon and nitrogen and their relationship to microbial activity. A soil health calculation number can range from 0 to over 50, and should increase over time if the soil is being managed sustainably. For the September 2014 data, both Solvita levels and Soil Health Calculation scores were higher in plots seeded at 60 seeds/ft^2 (47.9 ppm and 9.4, respectively) than in the 40 seeds/ft^2 plots (38.2 ppm and 8.0, respectively), with the 20 seeds/ft^2 plots in between (45.1 ppm and 9.0, respectively); there were no significant effects from the three cover crop mixes. These data suggest that even with our poor second year cover crop establishment, the highest cover crop seeding rate seems to be most beneficial to the soil microbial community so far. Overall, the positive trends for microbial activity and Soil Health we're seeing after two years of cover cropping and no-till are promising, and we hope to see those trends continue over the next year.

Slug Predation

Slugs continued to be a major problem for establishment of both the sweet corn and cover crop seedlings in the second year of this no-till study. We applied metaldehyde slug bait shortly after emergence of both crops, but there was still extensive damage to the cover crop seeds and seedlings that combined with other factors to produce a near complete crop failure. Slug control is expensive for growers due to the common need for multiple applications of slug bait treatments. Starting in 2014, the US EPA imposed new restrictions on the use of metaldehyde slug bait, limiting its use for certain seed crops (Lies, 2014; US EPA, 2007). Another less toxic slug bait, iron phosphate, has shown to be as effective as metaldehyde, but it is more expensive (Anderson et al., 2013). Deep and frequent tillage and removal of crop residue or surface organic matter are the two main recommendations for cultural controls of slugs (Dreves and Fisher, 2013), but are obviously at odds with the soil health improvement goals of cropping systems using cover crops and no-till. It appears that slug control will continue to be a major challenge for no-till systems in western Oregon, where slug populations are among the highest in the world.

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